

Supersymmetric $U(1)_B \times U(1)_L$ model with leptophilic and leptophobic cold dark matters

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(Dated: June 8, 2011)

We consider a supersymmetric model with extra $U(1)_B \times U(1)_L$ gauge symmetry that are broken spontaneously. Salient features of this model are that there are three different types of cold dark matter (CDM) candidates, and neutral scalar sector has a rich structure. Light CDM with $\sigma_{\text{SI}} \sim 10^{-3 \pm 1}$ pb can be easily accommodated by leptophobic dark matter (χ_B) with correct relic density, if the $U(1)_B$ gauge boson mass is around $2m_{\chi_B}$. Also the PAMELA and Fermi/LAT data can be fit by leptophilic CDM with mass ~ 1 TeV. There could be interesting signatures of new fermions and new gauge bosons at the LHC.

Proton decay is possible only if both baryon and lepton numbers are broken. The current bound on proton life time indicates that both of these symmetries are extremely good ones. This fact might indicate that these symmetries are exact local symmetry, rather than global symmetries which are always expected to be broken to some extent.

Recently the gauged $U(1)_B \times U(1)_L$ model without supersymmetry has been constructed and phenomenological consequences of this model have been discussed [1]. Anomaly can be cancelled by introducing new full family of the opposite (or the same) chiralities from the SM fermions with the baryon number $-1(1)$ and lepton number $-3(3)$, respectively. Now, let us focus on the model with the opposite chirality.

Basic features of the model with a CDM candidate are additional scalars, S_L and S_B that break the gauged $U(1)_L$ and $U(1)_B$ at some scale, and a new stable scalar X which makes new heavy quark decay into light quark and X . The model also has interesting aspects for neutrino physics and leptogenesis [1].

The model considered in Ref. [1], being a nonsupersymmetric model with fundamental scalars, does not address the fine tuning problem of Higgs mass². If we consider the fine tuning problem seriously, we have to include another new physics at EW scale. Softly broken supersymmetry at EW scale is probably the simplest way to resolve this issue. Furthermore, the lightest neutral particle can be stable in supersymmetric models with R-parity. The extension of the gauged $U(1)_B \times U(1)_L$ model to SUSY can realize not only R-parity spontaneously, but also additional CDM candidates. There is a possibility that we can provide several experimental results with a comprehensive explanation.

In this letter, we consider SUSY extension of $U(1)_B \times U(1)_L$ model with new full family fermions with opposite chirality, and study its phenomenological consequences. (The model with the same chirality fermions is similar to the MSSM₄, and we do not pursue this possibility in this letter.) The matter content of our model is similar to that of Ref. [1], but we add lepton number carrying superfield X_L and \bar{X}_L , which can make leptophilic CDM.

Some of the salient features of our model are that both the dark matter and neutral Higgs boson sector become very rich with multicomponent. There are three CDM candidates, leptophilic and leptophobic and the usual lightest neutralino. There are ten neutralinos and ten neutral scalars. After baryon and lepton numbers are broken spontaneously, there are mixing among new neutral fermions (scalars) and those in the minimal supersymmetric standard model (MSSM).

In the SUSY $U(1)_B \times U(1)_L$ model, all gauge anomalies are cancelled by introducing one new family of quarks and leptons with opposite chiralities from the SM fermions. (See Table.I.) $S_B(\bar{S}_B)$ and $S_L(\bar{S}_L)$, whose charges are $n_B(-n_B)$ and $2(-2)$, are the fields which break $U(1)_B$ and $U(1)_L$. In order to realize spontaneous $U(1)_B$ and $U(1)_L$ breaking, we set soft SUSY breaking terms of $S_B(\bar{S}_B)$ and $S_L(\bar{S}_L)$, squared mass terms and B-terms, to ones in appropriate parameter regions like MSSM higgs without assuming specific mediation mechanism.

S_L and \bar{S}_L couple with the right-handed neutrino, N_i , and generate heavy Majorana masses. X_B and \bar{X}_B are the fields which make extra quarks, such as Q' , decay. If we assume that superpotential is a polynomial, extra quarks cannot decay without X_B and \bar{X}_B . We forbid couplings between $S_B(\bar{S}_B)$ and SM particles according to the charge assignment in Table I. Compared with non SUSY model of Ref. [1], we have additional X_L and \bar{X}_L with $U(1)_L$ charges $\pm n_L$ which can be leptophilic CDM. In order to forbid X_L coupling to leptonic bilinear, we impose $n_L \neq 0, \pm 1, \pm 2, \pm 4$. The charge of S_B, n_B , also satisfies $n_B \neq 0, \pm 1/3, \pm 2/3, \pm 4/3$ to forbid direct couplings between $S_B(\bar{S}_B)$ and $X_B(\bar{X}_B)$ in renormalizable superpotential. For $n_L = \pm 1$ and $n_B = \pm 4/3$, operators like $S_L X_L^2$ and $S_B X_B^2$ are allowed and X_L and X_B could be stable, but we assume that $n_L \neq \pm 1$ and $n_B \neq \pm 4/3$ for convenience.

Superpotential of the model is given by

$$W = W_{\text{quark}} + W_{\text{lepton}} + W_{\text{bilinear}} \quad (1)$$

where the first two are Yukawa terms and the last one is the bilinear term:

$$W_{\text{quark}} = Y_{ij}^u Q^i U^j H_u + Y_{ij}^d Q^i D^j H_d + Y_u' Q' U' H_d + Y_d' Q' D' H_u + \lambda_{Q_i} X_B Q' Q^i + \lambda_{U_i} \overline{X_B} U' U^i + \lambda_{D_i} \overline{X_B} D' D^i \quad (2)$$

$$W_{\text{lepton}} = Y_{ij}^l L^i E^j H_d + Y_{ij}^\nu L^i N^j H_u + Y_l' L' E' H_u + Y_\nu' L' N' H_d \\ + \lambda_i S_L L' L_i + \lambda_{ij} N^i N^j S_L + \lambda_{N_i} N_i \overline{S_L} N' + \lambda_{E_i} \overline{S_L} E' E_i \quad (3)$$

$$W_{\text{bilinear}} = \mu H_u H_d + \mu_{X_B} X_B \overline{X_B} + \mu_B S_B \overline{S_B} + \mu_{X_L} X_L \overline{X_L} + \mu_L S_L \overline{S_L}. \quad (4)$$

TABLE I: $SU(3)_C \times SU(2)_L \times U(1)_Y \times U(1)_B \times U(1)_L$ charges of fields in this model. $i, j, k = 1, 2, 3$ are the generation indexes for the SM fields, and the primed fields are newly added to cancel all the gauge anomalies. All fields are left chiral superfields.

Field	Charges	Fields	Charges
Q^i	$(3, 2, 1/6; 1/3, 0)$	Q'	$(\bar{3}, 2, -1/6; -1, 0)$
U^i	$(\bar{3}, 1, -2/3; -1/3, 0)$	U'	$(3, 1, 2/3; 1, 0)$
D^i	$(\bar{3}, 1, +1/3; -1/3, 0)$	D'	$(3, 1, -1/3; 1, 0)$
L^i	$(1, 2, -1/2; 0, 1)$	L'	$(1, 2, 1/2; 0, -3)$
E^i	$(1, 1, 1; 0, -1)$	E'	$(1, 1, -1; 0, 3)$
N^i	$(1, 1, 0; 0, -1)$	N'	$(1, 1, 0; 0, 3)$
H_u	$(1, 2, 1/2; 0, 0)$	H_d	$(1, 2, -1/2; 0, 0)$
X_B	$(1, 1, 0; 2/3, 0)$	$\overline{X_B}$	$(1, 1, 0; -2/3, 0)$
S_L	$(1, 1, 0; 0, 2)$	$\overline{S_L}$	$(1, 1, 0; 0, -2)$
S_B	$(1, 1, 0; n_B, 0)$	$\overline{S_B}$	$(1, 1, 0; -n_B, 0)$
X_L	$(1, 1, 0; n_L, 0)$	$\overline{X_L}$	$(1, 1, 0; -n_L, 0)$

In this model, lepton and the baryon numbers are gauge charges, so that there are no usual R -parity violating couplings. Assuming that n_B is $2k/3$ ($k \neq 0, \pm \frac{1}{2}, \pm 1, \pm 2$), where k is integer, $U(1)_B \times U(1)_L$ breaks to $\tilde{Z}_{2B} \times Z_{2L}$. R -parity, $(-1)^{3B+L+2j}$, is automatically conserved after $U(1)_B \times U(1)_L$ symmetry breaking.

We assume that X_L and X_B do not get nonzero VEVs, in order to avoid large mixing between Q' and Q_i which would generate large FCNC. In the lepton sector, the yukawa couplings, such as λ_i , generate mass mixing because of nonzero $\langle S_L \rangle$. For example, $\mu \rightarrow e, \gamma$ process gives strong constraints on the yukawa couplings,

$$|\lambda_{Ee} \lambda_\mu| \lesssim \frac{m_\nu^3}{\langle \overline{S_L} \rangle \langle S_L \rangle} \times \frac{10^{-13}}{\text{GeV}}. \quad (5)$$

There are two charged scalars H^\pm as in the MSSM. The neutral scalar bosons are much richer than the MSSM:

- CP-even: $(\text{Re}(S_B), \text{Re}(\overline{S_B})), (\text{Re}(S_L), \text{Re}(\overline{S_L}))$
- CP-odd: $(\text{Im}(S_B), \text{Im}(\overline{S_B})), (\text{Im}(S_L), \text{Im}(\overline{S_L}))$

After $U(1)_B \times U(1)_L$ is spontaneously broken, there are mixings between the MSSM neutral Higgs bosons and L and B charged neutral scalars (S_B^0, S_L^0 and their conjugates) at one-loop level. While MSSM Higgs bosons couple to the fermion masses, the L or B charged scalars couple to the baryon and lepton numbers of fermions. Therefore after making field redefinition to the physical mass eigenstates, the neutral scalars can have decay patterns which are different from the MSSM Higgs bosons, especially for light fermions for which $m_f/v \sin \beta (\cos \beta) \sim g_B$ or g_L . The mixing and upper bound for the lightest $U(1)_B$ higgs will be very small, like $O(10)$ GeV, in the parameter region we discuss below. We expect the lightest to evade constraints on colliders [2], but more detailed studies are in need [3].

The neutralino sector of our model is also enlarged due to the new gauge symmetries. Let us call λ_B and λ_L the gauginos of $U(1)_B$ and $U(1)_L$, respectively. There are two more sets of neutral fermions, $(\lambda_B, \widetilde{S_B}, \widetilde{\overline{S_B}}) \equiv \Psi_B^{0T}$, and $(\lambda_L, \widetilde{S_L}, \widetilde{\overline{S_L}}) \equiv \Psi_L^{0T}$ in addition to the usual 3 neutralinos ($\widetilde{B}, \widetilde{W^3}, \widetilde{H_u}, \widetilde{H_d}) \equiv \Psi_{GH}^{0T}$ (gauginos plus Higgsinos). All in all there are 10 neutral Majorana fermions. After the gauge symmetry of our model is spontaneously broken into $SU(3)_C \times U(1)_{\text{em}}$, all these neutral fermions mix with each other either at one-loop or two loop level. The mass eigenstates $\chi_{n=1,2,\dots,10}^0$ of ten neutral fermions are linear combinations of Ψ_B^0, Ψ_L^0 and Ψ_{GH}^0 .

$\widetilde{X_L}(\widetilde{\overline{X_L}})$ and $\widetilde{X_B}(\widetilde{\overline{X_B}})$ are also neutral, but they do not have mixing with λ_B according to the zero VEVs of the bosonic superpartners. That is, they can be dark matters of Dirac fermion and respect accidental $U(1)$ symmetry. Let us denote the dirac fermions as just $\widetilde{X_B}$ and $\widetilde{X_L}$ in the following sections. The bosonic sectors of X_L and X_B also have global $U(1)$, so that they cannot have mixing with the other neutral scalars, or the mixing could be very small.

Our model has multicomponent CDM's due to three conserved quantities: the usual R -parity and two accidental global symmetries, $U(1)_{X_B}$ and $U(1)_{X_L}$:

$$U(1)_{X_B} : (X_B, \overline{X_B}, Q', U', D') \rightarrow (e^{i\alpha} X_B, e^{-i\alpha} \overline{X_B}, e^{-i\alpha} Q', e^{i\alpha} U', e^{i\alpha} D') \quad (6)$$

$$U(1)_{X_L} : (X_L, \overline{X_L}) \rightarrow (e^{i\beta} X_L, e^{-i\beta} \overline{X_L}) \quad (7)$$

The SM particles, extra quarks and leptons are R -parity even, whereas their superpartners and all gauginos are R -parity odd. While the extra neutral bosons, such as S_B , are R -parity even, their superpartner is odd. R -parity realizes a stable particle in our model, so that χ_1^0 , $\widetilde{X_B}$, and $\widetilde{X_L}$ are good candidates for CDM.

Besides, both X_B and $\widetilde{X_B}$ carry $U(1)_{X_B}$ charge $Q_{X_B} = +1$, and their conjugates carry $Q_{X_B} = -1$. For leptonic fields, $X_L, \widetilde{X_L}$ (and their conjugates) carry $Q_{X_L} = 1(-1)$, whereas all the other particles carry no $U(1)_{X_L}$ charge. There are 2 complex scalars charged under only $U(1)_{X_B}$, but they are not degenerate generally because of B-term, $B_X \widetilde{X_B} X_B$. The heavier scalar field can decay to 2 quarks and the lightest scalar. Unless the lightest is heavier than both $\widetilde{X_B}$ and χ_1^0 , it cannot decay because of the global symmetry. The lightest $U(1)_{X_B}$ charged scalar particle, X_{B1} , can be leptophobic CDM. The $U(1)_{X_L}$ charged fields X_{L1} (scalar) is also a good leptophilic CDM candidate.

Eventually, there are 1 Majorana fermion, 2 Dirac fermion, and 2 complex scalar fields as good CDM candidates in this model. Among them, 3 particles can be stable corresponding to 3 global symmetries, and the other 2 fields decay to 2 CDMs. It depends on the mass spectrum which fields are stable or not, and each sets must allow extra quarks to decay. The extra quark, such as Q' , is R -parity even and charged under $U(1)_{X_B}$, so that at least lighter X_{B1} or $\widetilde{X_B}$ must be lighter than Q' . If X_{B1} is heavier, both of $\widetilde{X_B}$ and χ_1^0 must be lighter than Q' because of R -parity.

Generally speaking, $U(1)_{X_B}$ is anomalous and $U(1)_{X_B}$ breaking terms, such as $X_B S_B^{-2/3n_B} = X_B S_B^{-\frac{1}{k}}$ (with $|k| \neq 0, 1/2, 1, 2$), can be written down, including non-renormalizable terms. However, such breaking terms allow mixing between $\widetilde{X_B}$ and neutralino, because X_B gets nonzero VEV through tadpole terms like $X_B \langle S_B \rangle^{-\frac{1}{k}}$. If our superpotential is a polynomial in superfields, such dangerous operators would be forbidden as far as $|k| \geq 1$ is satisfied, and the stability of X_{B1} and dirac CDM, $\widetilde{X_B}$, could be guaranteed. This argument can be applied to $U(1)_{X_L}$, and n_L cannot be even integer and ± 1 to respect $U(1)_{X_L}$.

Since there are many new particles and parameters compared with the MSSM, it would be easy to imagine that there are rich phenomenology of this model both at colliders and in CDM. In order to illustrate the richness of our model, we choose to fit both (arguably) intriguing signature of light cold dark matter (lCDM) from direct detection experiments by CoGeNT [4] and DAMA/LIBRA [5], and positron excess observed by PAMELA [6] and Fermi/LAT satellite [7]. We consider

the scenario that there are one light leptophobic CDM, $\widetilde{X_B}$ or X_{B1} , lightest neutralino, and one heavy leptophilic CDM, $\widetilde{X_L}$ or X_{L1} .

CoGeNT and DAMA/LIBRA results are challenged by CDMS [8] and XENON10 [9], so we need very careful analysis to realize them in our model [10]. Even if they are excluded, there is a region close to the CoGeNT and DAMA signal region, where lCDM χ_B can have $\sigma_{SI} \sim 10^{-3\pm 1}$ pb with an acceptable thermal relic density, as long as $M_{Z_B}/g_B \sim 1$ TeV and $M_{Z_B} \sim 2m_{\chi_B}$ which is not excluded by collider data (see Fig. 1 and related discussions).

Keeping this remark in mind, let us focus on the leptophobic lCDM scenario around the CoGeNT and DAMA/LIBRA signal region. We assume that the lCDM claimed by CoGeNT and/or DAMA/LIBRA is a leptophobic dark matter, $\widetilde{X_B}$ (X_{B1}), in our model.

From the claimed cross section $\sigma_{SI} \sim 10^{-40}$ cm² and the lCDM mass ~ 7 GeV [11], we can obtain a constraint on a combination of $m_{Z_B}/g_B \sim 1$ TeV, if the contributions of superparticles are negligible because of their TeV-scale masses. Using this constraint, we can constrain further the mass of m_{Z_B} by calculating $\Omega_{lCDM} h^2$ and assuming it is equal to or less than the WMAP measurement of Ω_{CDM} . We find that the relic density turns out too large for heavy m_{Z_B} . We can use the s -channel annihilation on the Z_B resonance in order to enhance the annihilation cross section, thereby getting the right amount of relic density for the cold dark matter. Then there is more or less unique value for $m_{Z_B} \sim 2m_{lCDM} \sim 14$ GeV, with very small $U(1)_B$ gauge coupling $\alpha_B \sim 10^{-5}$. See Fig. 1 for detail. The X_{B1} CDM does not have S-wave contributions, so that the allowed region is narrower. Squark exchanging could also contribute to the relic density through the t -channel annihilation, but it would be difficult to enhance the annihilation cross section.

Such a light $U(1)_B$ gauge boson with a weak gauge coupling is definitely out of reach at the current searches from colliders and low energy processes [12, 13]. It would be interesting and important to search for such light leptophobic gauge boson at the upcoming experiments.

Positron excess observed by PAMELA collaboration [6] might be due to dark matter pair annihilation into charged lepton pairs. There are explicit models based on leptophilic $U(1)$ symmetries [14, 15]. Since our model has lepton charged carrying neutral scalar (X_{L1}) or fermion ($\widetilde{X_L}$) that couples only to leptons due to the gauged $U(1)_L$ and supersymmetry, we could try to fit PAMELA data using this leptophilic dark matter.

In order to realize PAMELA, we have to consider large annihilation cross section, compared with $\langle \sigma v \rangle \sim 1$ pb

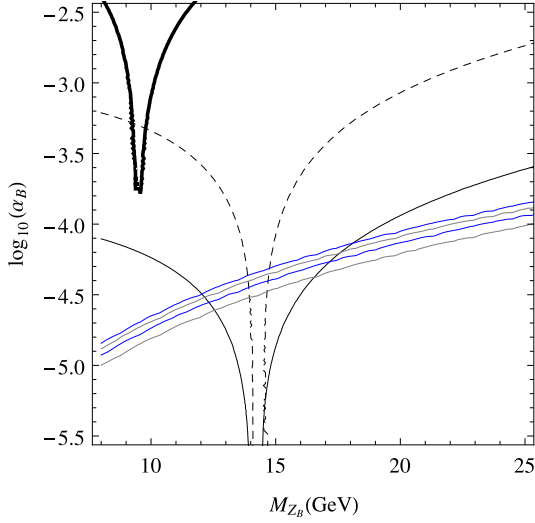


FIG. 1: Allowed region in the $(\log \alpha_B, M_{Z_B})$ plane for $m_{\text{ICDM}} = 7$ GeV, that is consistent with WMAP data, is the inside of each 2 line, where the leptophobic ICDM is bosonic X_{B1} (dashed lines) or fermionic \widetilde{X}_B (solid lines). Inside of thick black line is excluded by hadronic decay of $\Upsilon(1S)$. The bands within two blue lines and two gray lines are DAMA/LIBRA and CoGeNT regions [11].

which is favored by WMAP data, $\Omega h^2 \sim 0.11$. In our model, its pair annihilation channels will be

$$\widetilde{X}_L \widetilde{X}_L^\dagger \rightarrow Z_L^* \rightarrow ll, \text{ or } Z_L Z_L \rightarrow 4l's.$$

The latter is dominant if Z_L is lighter than \widetilde{X}_L . In that case, Sommerfeld enhancement could work at low energy like $\langle \sigma v(T_0) \rangle \sim S \langle \sigma v(T_0) \rangle_0$. In the Fig. 2, we can see the enhancement and the relic density with $m_{\text{CDM}} = 3$ TeV. However, g_L and M_{Z_L} are strongly constrained by the experiments: e, ν_μ scattering constrains M_{Z_L}/g_L as $M_{Z_L}/g_L \gtrsim 1.4$ TeV [16], and the LEP-II bound, $M_{Z_L}/g_L \gtrsim 6$ TeV, which is discussed in $U(1)_{B-L}$, could be applied to our model [17].

We notice that it is difficult to find the favored region with large S according to Fig. 2. The heavier \widetilde{X}_L with large S could avoid the constraints, but such heavy \widetilde{X}_L pair annihilations may produce high energy neutrinos (upto the mass of parent \widetilde{X}_L) of 3 flavors at the same rates, which may cause conflict with the cosmic observation [15].

Another CDM also contributes to the relic density, but if it has a heavy mass, like 100 GeV, the contribution could be enough small, as several works have discussed so far. For example, it has been discussed that yukawa coupling, $\lambda_b X_{B1} b' b$, can realize not only small relic density of X_{B1} but also the favored direct scattering cross section in Ref. [18]. If χ_1^0 is MSSM-like CDM, Z boson and Higgs exchanging are helpful [19].

Kinematic mixing terms among $U(1)_B$, $U(1)_L$ and $U(1)_Y$ are allowed by those gauge symmetries, and gener-

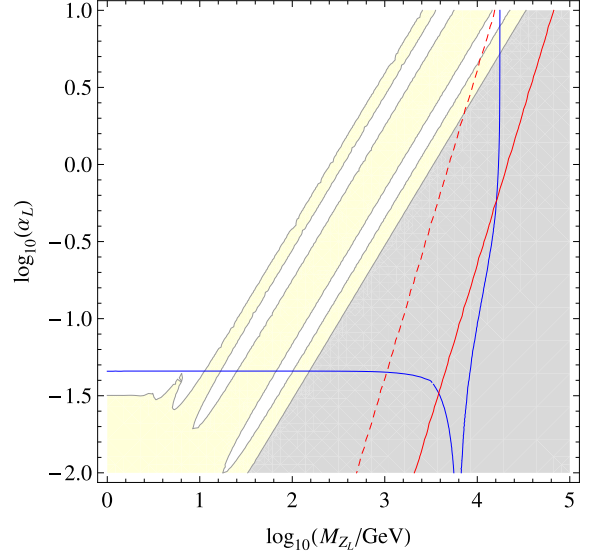


FIG. 2: This figure shows the relic density and Sommerfeld enhancement of \widetilde{X}_L with $m_{\text{CDM}} = 3$ TeV and $Q_{X_L} = 1$. The above of the blue line corresponds to $(\Omega h^2)_{X_L} \leq 0.11$. In the white, yellow and gray regions, the enhancements are $S \geq 100$, $100 \geq S \geq 10$, and $10 \geq S$. The left sides of the dashed red and the red lines are excluded by e, ν_μ scattering and LEP-II bound.

ated radiatively. Their upper bounds are very tight [13], but the radiative correction is very tiny if gauge couplings are small enough as in our scenario. In any case, the initial condition must be controlled to suppress the kinematic mixing, as discussed in Ref. [13].

The conserved quantities are $U(1)_{X_B}$, $U(1)_{X_L}$ charges and R -parity. Note that X_B and X_L are R -parity even, whereas their fermionic superpartners are R -parity odd. Let us discuss some decays of new particles as examples (χ_1^0 is the lightest R -):

$$\lambda_B \rightarrow q\bar{q}^* \rightarrow q(q\chi_1^0) \quad (8)$$

$$X_B \rightarrow q\bar{q}\chi_1^0 \widetilde{X}_B \quad (9)$$

\widetilde{S}_B and its conjugate mix with λ_B and decay into $q\bar{q}^* \rightarrow q(q\chi_1^0)$. Similarly, $\lambda_L, \widetilde{S}_L$ and X_L decay into $l\bar{l}\chi_1^0 \widetilde{X}_L$. Unlike the MSSM, the R -parity even scalar X_B can decay into $q\bar{q}\chi_1^0 \widetilde{X}_B$ through two processes:

$$\begin{aligned} X_B &\rightarrow \psi_{X_B} \lambda_B \rightarrow \widetilde{X}_B (q\bar{q}\chi_1^0) \\ &\rightarrow \widetilde{Q}' \widetilde{q}_i^* \rightarrow (q\widetilde{X}_B)(q_j\chi_1^0) \end{aligned}$$

if kinematically allowed. However X_B can be stable if this decay is kinematically forbidden. This is guaranteed by conservations of $U(1)_{X_B}$, $U(1)_{X_L}$ charges and R -parity. If \widetilde{X}_B is heavier than X_B , the reverse process will occur if kinematically allowed. The new heavy (s)quarks can be produced at the LHC: $pp \rightarrow t'\bar{t}', \widetilde{t}'\bar{\widetilde{t}}'$. If X_B is lighter than \widetilde{X}_B , the main decay modes of t' and

\tilde{t}' are $t' \rightarrow qX$ and $\tilde{t}' \rightarrow X_B \tilde{q} \rightarrow X_B q \chi_1^0$, respectively. If \tilde{X}_B is lighter than X_B , then the main decay modes of t' and \tilde{t}' are $t' \rightarrow \tilde{X}_B \tilde{q} \rightarrow \tilde{X}_B q \chi_1^0$, and $\tilde{t}' \rightarrow \tilde{X}_B q$. If some of the decays are kinematically forbidden, t' or \tilde{t}' will be stable and hadronized, and thus strongly constrained by heavy charged particle search. Finally, new scalars S_B , S_L and their conjugates will mix with neutral Higgs and will decay into lighter fermions or weak gauge bosons or Z_B 's.

There are strong constraints on t' and b' masses. They can decay to quarks and CDM, but such exotic quarks search could be replaced by SUSY particle ones, such as squark decay process, $\tilde{t} \rightarrow \chi_1^0, t$. In Ref. [20], the bounds for t' and b' masses, which correspond to the case with scalar X_B CDM, are discussed in that way: the lower masses are more than 300 GeV. If this argument is applied to our model, Landau poles of Yukawa couplings appear at TeV scale.

We must also care about EWPT bound for higgs mass, extra quark masses, and all sparticle masses. The discussions in Ref. [21] can be applied if superparticle and extra higgs contributions are small.

In this letter, we constructed supersymmetric extension of $U(1)_B \times U(1)_L$ model, extending the works by Wise et al. [1]. The model is anomaly free, with very rich phenomenology in terms of colliders, Higgs bosons, flavor physics and CP violation, and most notably CDM. The most interesting aspect of this model is the multi component CDM's. The model houses both leptophilic and leptophobic CDM's in addition to the usual lightest neutralino, and the stability of these CDM's are consequence of gauge symmetry and particle contents, not of *ad hoc* Z_2 symmetry. Furthermore, the leptophobic CDM can be light enough to accommodate the CoGeNT/DAMA signal region, with correct amount of relic density. The leptophilic CDM can be heavy enough to explain the positron excess observed by PAMELA and Fermi/LAT. However, it seems to be difficult to explain PAMELA without assumption of large boost factor.

We could describe the simpler scenario that the lightest neutralino approximately becomes leptophilic because of small mixing, and realizes PAMELA data. Furthermore, our model has an interesting signature that the missing E_T signature could be due to two different DM (with different masses and spins). We touched relevant features of our model with a wide brush, relegating the details of phenomenology to the future works [3].

We thank to P. Gondolo and M. Drees for useful discussions. This work is supported in part by SRC program

of National Research Foundation (NRF) through Korean Neutrino Reactor Center (KNRC), Seoul National University.

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